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ABSTRACT

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Theories and Strategies Related to Measurement in Individualized Instruction

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16. Abstract

One of the basic problems in relating learning theories to instructional strategies is that traditionally learning theory has researched the micro unit whereas the instructional environment studies the macro unit. Traditionally, instructional strategy research and development takes the learner as he comes, an integrated organism. In learning theory research, there is control and limitation on the structure of the learning materials, whereas instructional subject-matter is rich in potential organization [illegible] ordering. Moreover, learning theory [illegible] in a subset of factors relevant to instruction. This paper addresses problems in bridging gaps between learning research and instructional development by considering the relevance of the premises of learning theory and identifying some promising directions that draw on the concepts of cybernetics and information processing.

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THEORIES AND STRATEGIES RELATED TO MEASUREMENT IN INDIVIDUALIZED INSTRUCTION

Robert J. Seidel

One of the basic problems in relating learning theories to instructional strategies is that traditionally, and probably by their respective natures, in learning theory (relating to a general scientific body of knowledge) research has been conducted on the micro unit whereas in the instructional environment the macro unit has been studied. This is not surprising, since the purpose of learning research has been to generate a body of scientific knowledge regarding *description*—laws of behavior change. Education and the development of better instructional strategies have the practical goal of *prescription*—ways and means of maximizing performance in a specific, realistic setting. Therefore, research on learning theories requires the creation of divergent experimental conditions; instructional development generates the focusing of strategy for a particular environment. Traditionally, instructional strategy research and development takes the learner as he comes, an integrated organism. In learning theory research, there is control and limitation on the structure of the learning materials, whereas instructional [illegible]ject-matter is rich i[illegible]ential organization and hierarchial orderings, as shown in Figure 1.

Learning and Instruction Compared

	LEARNING THEORY	DIDAKTICS[1]
Dimension	Micro Unit	Macro Unit
Environment	Divergent Conditions	Particular Convergent Conditions
Structure of Information Processing	Limited, Restrictive, and Simple	Rich in Organization and Hierarchical Orders
Purpose	Descriptive, General Laws of Behavior Change	Prescriptive, Maximize Performance in Specific Natural Settings

[1]The usage here is the German reference to strategies and environmental considerations for instruction. It is a more inclusive term than simply "instruction" since it includes objectification and formalization where possible, of instructional parameters. For a more complete discussion, see "Kybernetische Grundlagen der Padagogik" by Dr. Helmar G. Frank, Agis-Verlag GmbH, Baden-Baden, Germany, 1969, page 364.

Figure 1

In another sense, learning theory research deals in a subset of the set of factors relevant to instruction; namely, the process whereby acquisition arises from experience. Instructional strategies, however, must link this process to others; for example, to signal detection theory relevant to perceiving appropriate student attributes, and to motivation as a topic governing situational incentives.

For these and related reasons, research on the instructional environment has been labeled "applied" and that in the learning laboratory, "basic." How much of the dichotomy is conceptually real, how much has been a practical necessity? What meaningful relationships are to be found?

Psychology is of an age to reconsider historical distinctions. To relate the two domains of learning theory and instructional strategy, we must ask whether a bridge can and should be built, and if so, how? Hilgard in a recent survey (1964) stated this need, ". . . we believe that scientific psychology of learning has the obligation to go all the way from theory to practice, using criticized data in every step. This involves a division of labor, of course, but with collaborative effort and mutual good will all along the line."

I will address some of the problems in this paper and point to some avenues for solution. The relevance of the premises of learning theory to individualized instruction, to the nature of experimental variables, to the criteria of significance, will be considered; also, the possible limitations inherent in the language and paradigms of classical learning theory, hoping to identify some promising directions.

If we are to improve instructional proficiency through the application of better instructional strategies based on learning theories, we will have to take an analytic view of the macro unit, of the attribute structure of both the course materials and the student image. The latter, which could be represented by a vector composed of the perceived relevant attributes, must be made explicit. With respect to the application of learning theory to instruction, difficulties arise for the most part from the nature of the learning theories in dealing with the microcosm or microstructure of traditional, learning theory instructional material—usually very artificial (i.e., disconnected discourse and generally meaningless terms in conjunction with use of criteria that are internal to list learning rather than application oriented). The learning theories then generate research based on the perceived elements of the microstructure, such as isolated stimulus units identified with restricted physical properties and restricted response properties.

If the learning theories are to be extended from the molecular description within the laboratory to application in dealing with the macro units and connected discourse problems within the instructional environment, a bridge must be made between the hypotheses and research set forth within so-called pure learning studies and those dealing with the problems of the individualized instructional environment. For example, the very concept of research in a laboratory learning environment is such that it deals with statistical significance of differences; in the instructional environment, however, it is not sufficient to identify statistically significant differences between conditions—there must be practical significance to the findings as well. Clearly, this is not at all different from the problems industrial psychology has had for decades: If the cost of a difference in method outweighs the gain from the method, the so-called advantageous condition is not warranted, even if the advantage *is* statistically significant. If there is a difference between pure research and applied research, it is found in this area. (MacCaslin and Cogan, 1968; Finan, 1962).

Another area of great importance in any study of behavioral change, particularly learning, is the ubiquitous, ill-defined concept of motivation. In learning research, motivation is usually maintained as a constant, and generally at a high level, unless one is studying latent or incidental learning. With motivation controlled, one varies other independent variables of interest, such as length of list and frequency of occurrence of items, and observes dependent variables related to learning. But the popularity of utility theory in the 1950s and 1960s has clearly shown that motivation cannot be taken for granted in a human learning environment. It is a particularly important and frequently variable factor in instructional environments, and is especially highlighted in individualized instruction. Too often problems of motivation (and incentives) are overlooked or treated as "after-thoughts" or necessary uncontrollable evils in a system. However, you can lead a student to material, but you can't make him think—or attend, or learn.

Learning theory research until very recently could be characterized by maximum control: control over the exact nature of the imput (instructional material), the implicit assumption of tabula rasa for the organism, and control over the limited, distinct, and relatively simple nature of the output or response from the subjects. This approach, particularly in the 40s and 50s, led to much more research with lower animals than with humans, and that is the root of one of the difficulties in applying learning theory to instructional strategy in an individualized instruction environment. Control and simplification of variables within the learning research were much more readily obtained by using lower organisms such as the popular hooded rat and his replacement, the two-legged animal, the pigeon. Extrapolating to human learning has given too much emphasis to illusory cross-species commonalities and ignored qualitative differences between species (Hilgard, 1965; Pressey, 1963; Seidel, 1967; Macdonald-Ross, 1969; Kopstein and Seidel, 1971). Hilgard, for example, comments, " . . . it is strange that the . . . view is not made more explicit—that at the human level there have emerged capacities not approached by the lower animals including other primates."

The most explicit example of an attempt to apply learning theory of the classical S-R behavioristic tradition has been that of operant conditioning. By and large, the problem with this approach, as with many of the other so-called comprehensive behavioral theories in psychology, has stemmed from the treatment of the organism as an empty entity and the concentration solely upon restricted input and limited output requirements. The resurgence of cognitive psychology and the respectability of attempting to look inside the organism probably were cued in the 60s by Hebb's Presidential address before the APA (*American Psychologist*, 1960) followed by *Plans and the Structure of Behavior* of Miller, Galanter, and Pribram and by Ausubel's work.

Information processing theories of late, with analogies to computer software, have come into the ascendancy within the field of learning research. An example relevant to the area of motivation and the concept of cognitive motivation is indicated in a recent statement, "Controlling intrinsic motivation is a matter of providing an organism with circumstances that provide a proper level of incongruity with the residues of previous encounters [of course the proper level of incongruity is the difficult decision to make] with such circumstances that the organism has stored in his memory—the 'problem of the match' between incoming information and that already stored" (Sears and Hilgard, 1964). More recently, the use of cybernetics (e.g., Pask, 1969) and its tools has shown some promise for handling the problems of understanding the functions of the human organism in a learning and instructional environment. In fact, Pask's approach to an adaptive algorithm for maintaining the informational match incorporates the strategy of optimal incongruity just noted.

It is not the intent here to review or evaluate the literature. Suffice it to say that the problems in applying learning theories to instructional strategies require a global view of the informational requirements of the instructional system. It has been asserted that "the era of the great debate among the major theories is over." (Hilgard, 1964) Moreover, the problem of dealing with information, with the macro unit in instruction, can best be studied and understood by process-oriented theories as opposed to the substantive approaches of the classical behavioristic theories.

In a process-oriented theory, we consider the organism to be capable of processing information of varying types, of varying units, and capable of providing a varied set of outputs. We do not do justice to the varieties of output if we call them "responses." Examples of these kinds of research and approaches are found in the cybernetic-based research, the equilibrium theories referred to by Back (1961) and the recent mathematical modeling approaches (e.g., Atkinson and his associates, cf. Shiffrin and Atkinson, 1969), particularly those dealing in potential processes of short-term and long-term memory, as well as in the Simon and Newell (1964), Simon (1968), and other artificial intelligence approaches. The languages that are used with these points of view are much

richer in that they concentrate on *form* and *process* and not on restricted substance such as a stimulus defined by a wavelength or a response restricted to left-right turn in a T-maze or a lever-press (arbitrarily simplified subsets of information input and output). Moreover, they permit a look—or speculation—on the inside of the "black box" of the organism. This is not to say that the answers to the problems of instructional strategies are at all self-evident.

Sharp reversals in perspective, however, are important in science. Consider, for example, the development in physics that led to understanding motion. It did not come about until there was a reversal from the accepted point of view. Instead of continuing to puzzle over motion as a special case of rest, viewing rest as a special case of motion, enabled physicists to explain both phenomena with equal ease using the same set of concepts. So, too, will psychology benefit from a change in perspective. S-R learning theory has been bent, stretched, overlaid in multiples, and all but twisted to a totally unrecognizable form in trying to treat complex human learning (Millenson, 1967, provides a good example of this). To illustrate this tortuous reasoning one can consider human problem solving and Gagne's comment " . . . if one wishes to speak of 'correct responses' in problem solving as opposed to 'correct answers,' he must use the phrase in a purely metaphoric sense." (1964, p. 301) There are also instances with lower organisms where problems of S-R explanation arise (Shaw and Seidel, 1969).

If one considers earlier attempts at mathematical modeling, one can ask, what role does the *individual* with his unique set of characteristics play within this theoretical approach? Modeling, taken in the simplest form, the one-element model approach (Bower, 1961), had been based on the assumption there is one learning parameter, "c." But if we are serious about individual differences, that "c" should at least have a subscript referring to the particular student, and perhaps a superscript as well to consider the trial number or rather the stage in a course. More recently Hansen's work (1970) has yielded support for such a model in a paired associate instructional environment. He modified the prescriptive procedure to take into account individual learning parameters for subjects (learning to speak a list of words). More studies that include individual parameters are needed, and these should be extended to cover learning and instructional environments dealing with hierarchically organized materials and transfer criteria.

The significance of these studies, the math model research (e.g., Calfee, 1970; Smallwood, 1968), and the cybernetic studies (e.g., Pask, 1969; Landa, 1970; von Foerster, 1970) does not rest in their modest successes or failures as such. As Landa has stated,

> " . . . a cybernetic approach to the learning process did not exclude the psychological and pedagogical approaches . . . However, the significance of the cybernetic approach to instruction lay in the fact that specific psychological and pedagogical patterns of learning and instruction were examined from a more general, cybernetic point of view. Thanks to this, there opened up the possibilities of optimizing instructional control based on applying the achievements of a general theory of control and the sciences connected with it (mathematical logic, information theory, algorithm theory, regulating theory and the like) to this type of control."

Such a point of view stresses a marked and refreshing transition in approach from classical substance-oriented learning theories (Hull, 1952; Tolman, 1948; and Skinner, 1950) to a more formal, process type of approach. The term "information" or "input" is replacing the frustration-inducing term "stimulus" (Gibson, 1960; or Garner, 1970). While "response" is still used, we shall see increasing use of the term "output." It is more than coincidental that these terms are used in cybernetics. Input, processing, and output have little of the emotional attachments of the words over which psychologists have previously fought pitched battles.

At a minimum, the heuristic value of a change in focus based on finite state (or function) machines should receive careful consideration. As von Foerster says, "Instead of searching for mechanisms in the environment that turn organisms into trivial machines, we have to find the mechanisms within the organisms that enable them to turn their environment into a trivial machine," (p. 234, 1970). Translation: The organism is an active organizing force in its interaction with the environment, and we should study the processes underlying these dynamic (representational) capabilities.

The language, or rather meta-language, for theory construction purposes, of control processes accepts with equal ease analysis about informational input, whether it refers to an abstract rule or to the name of an object. The strength of the cybernetic view is that it does not prejudge psychological concepts (cf. Kopstein and Seidel, 1971). In this sense, it is parallel to the math modelers approach. Concepts are allowed to develop or die as the system exercises them either as inputs, transformations, or outputs. It is a methodology for quantifying the characteristics of dynamic systems. Pask (1969) has called attention to the fact that several levels of language are necessary to explain the teaching-learning process (also von Foerster, 1970). Most obviously the learner's language (symbolic control) must be descriptive of the learning problem at hand, while the instructor's language must be descriptive of the student's language. Note that at least two levels of abstraction are implied.

Scandura's approach to "structural" learning (1967) based on a set function language also illustrates the need for the language of learning theory to be more flexible to handle behavioral units or cognitive units (see Landa on algorithmic learning, 1970). Information available in the instructional environment, information able to be assimilated by the student, and information required to perform a particular task must still be precisely identified (e.g., Shaw and Seidel, 1969; Seidel and Kopstein, 1968), but they can be given operational meaning in broader semantic and pragmatic settings without the spectre of S & R. Moreover, the organism is given an *active* role in the learning process, and this processing makes the transition to individualized instruction at least more face-valid and opens up different kinds of research possibilities.

Let us consider the ingredients of a learning theory as they relate to individual characteristics of students, or subjects, as we call them in learning research, and then let us attempt to relate these characteristics to what is required in dealing with individualized instructional strategies.

In its simplest form, the language of learning theory has as its purpose, as noted earlier, the description *of* an acquisition process. Instructional strategy refers to the prescription *for* an acquisition process. That is, learning describes the process by which skills and knowledge are assimilated, whereas instructional research prescribes the management of the environment to make this process relevant to a situation. The question we must deal with is what are the implications of the various learning theories' primitives as they apply not simply to the overall instructional environment, but to an instructional agent's requirements for making decisions about managing, adapting, or controlling the instructional path for a unique individual.[1] Thus, in the latter case we refer to a set of rules, implicit or explicit, the instructional control processes, the purpose of which is to guide maximum performance on some specified criterion. Since we are concerned with the individual, we must ask how learning theories deal with the individual profile or the individual entity.

Individual differences in learning theory have been regarded in many instances as error variance surrounding a single function (e.g., the one-element model noted earlier). With this approach the individual is treated stochastically as if he really could be represented by a single set of parameters and errors of measurement to account for points off the curve (Figure 2a). Just a bit more complicated, alternatively, in some learning theories differences in the capabilities of individuals might be represented as a

very simple parameter of the curve to take into account initial performance level by using an individual intercept on the ordinate but still providing a single function with other parameters considered fixed. For individualized instruction and its implications for instructional strategies, the guiding premise should be that the profile or the entity which we call the individual student represents true variance. If we relate this to the intercept hypothesis just noted, then the strategy is to use this profile information for placement of the student with respect to initial position in a course (Figure 2b). Secondly, if the *slope* as well as the intercept is allowed to differ for individual students but is within the same class of functions, this individualized parameter has implications as well for the rate at which the student should be presented with the material to be mastered.

Hypothetical Information Processing Growth Functions

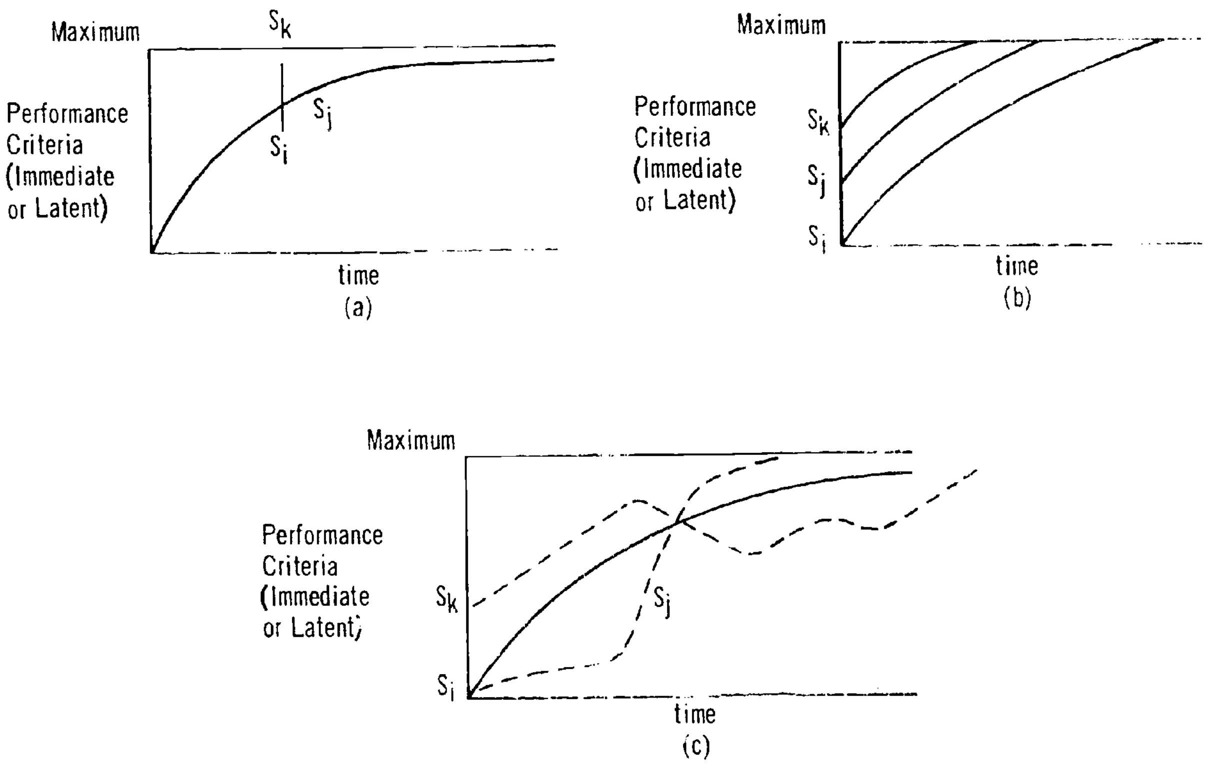

Figure 2

However, if we treat the individual as a profile of capabilities similar to Guilford's Structure of Intellect (1967), then the varied and dynamic nature of intellectual processing characteristics of an individual (or classes of persons, for practical purposes) dictate adapting by the use of available control processes (a) the type of representation and sequence of subject matter presented to a student, and (b) as required, the quantity of material per unit time. In short, different descriptive processes or learning functions for individuals may be appropriate, and unique prescriptive instructional paths to match the individual may be necessary (Figure 2c).

Thus, to apply learning theories to instructional strategies in the individualized instruction environment requires a fresh look at measurements, evaluations, and instructional actions. We must attempt to deal with the student as an individual with his own profile of characteristics, and, therefore, must continually diagnose his capabilities and momentary characteristics *as an individual*. Further, since the student is a dynamic

system—he is changing in his characteristics during the course of his within-instruction history—we must go to continual, diagnostic testing, and with reference points to the particular student and his profile (Stolurow, 1965). It would be inappropriate to use simply general normative statistics that concern stable traits, such as average class IQ or grade level. It is also insufficient to shift simply to criterion-referenced testing from normative testing without the dynamic considerations.

One of the challenging problems in dealing with the relationships between descriptive and prescriptive processes concerns establishing a consistent terminology to describe the activities of the various components within what we can call for the moment an "instructional system." Some (e.g., Hansen, 1970) have chosen to call the aspect of control processes under the influence of the instructional agent, "teaching strategy." The general term "instructional strategy" is more appropriate. Why? Because the inputs and outputs in relationship to one another from both the instructional agent point of view and the student point of view take the form of an attempt to maximize the output of the system. The instructional system case requires cooperative efforts so that all the control processes are operating in synchrony. The optimization that comes about is a balance between maximizing the inputs to the student and his outputs per unit time with respect to some criterion.

If we wished, as instructional agents, we could simply give a textbook assignment and ask that it be completed by the following morning. Or, in a computerized environment, we could display information to the student at the rate of 400 baud and do this continuously; this would certainly make the operation of the instructional agent, vis-a-vis maximization of information input to the student per unit time, very efficient. There would be no waiting time. However, the student processing would become a minimum because of information overload. Similarly, it would probably be very easy for the student to cope with very minute amounts of information per unit of time from the instructional agent, thereby maximizing his accuracy per unit of information, his speed per response per unit time of display, and so forth.

But, neither would result in maximizing the output of the system as measured by an end of course criterion test. What I am suggesting is that to maximize the output of the system requires optimizing the I/0 relationships between the two principal components within the instructional system: the learning strategy, and the teaching strategy—that is, optimizing the overall instructional strategy within the system by allocating resources in control processes between instructional agent on the one hand and the student on the other.

The key to optimal allocation of learner controls in the instructional decision process requires basic research in human learning to (a) identify those components of strategy selection and use, of which students are capable, (b) relate these components to individual characteristics, and (c) determine where program control can or cannot manage the same components. Applying the results to an educational environment, we could then arrive at a cost/effective justification for optimally allocating components of instructional decision making to students or to a program in an adaptive teaching system. Both Pask's cybernetic approach and the HumRRO approach (Seidel, *et al.*, 1969(a) and 1969(b); Seidel, 1969; Seidel and Kopstein, 1968) are directed toward this end.

Specific task transfer and the differential performance (DP) function elaborated by Bunderson (1967) provide a worthwhile attempt to relate abilities to the acquisition processes and provide a link between what we might call static versus dynamic processes. Viewed from the DP approach, mental abilities are overlearned acquisitions. The value of this proposition is that it bridges ability testing, learning processes, and instructional strategies. First it says consider the individual student to be a dynamic information processor rather than a composite of static traits. Second, from the work of Guilford, (1961, 1967) and subsequently of Bunderson (1965) and associates (Dunham, Guilford,

and Hoepfner, 1968) the assertion has given operational meaning to intellectual functioning as a set of processes appropriate to specific kinds of instructional tasks. Optimizing instructional strategy, then, involves matching the information-processing capabilities of the student to the informational requirements of the instructional tasks as the student moves through a course.

A start to new concepts and measures that would be applicable in this environment are:

(1) Instead of a static, normative approach to psychometrics, we need a view of measurement that is based on a changing individual with his own reference points. That is, not only what his beginning capabilities are, but relative to his set of characteristics, what types and rates of change take place in performance over different stages of learning.

(2) In the context of individualized instruction, we must represent the individual-learning combination as a vector, that is, locate the combination uniquely and dynamically within a sample space (Seidel, *et al.*, 1969). This space is described by the various points of intersection outlined by the dimensions and elements of the subject-matter structure, the data points making up the individual's personal characteristics, and finally, the interrelationships between the particular subsets of individual characteristics and the nature of the knowledges and performances required of a student at a moment of instruction. Stated another way, our task is to diagnose in a group of individual students where each is located in this n-dimensional sample and space by a set of coordinates based on the characteristics just noted. Once having made this assessment we must adapt the instruction to this changing individual or to the particular location described by the coordinates. Given the error that will occur in our making these assessments, the task of the control processes within the instructional system is to take advantage of the feedback to correct answers and to provide an increasingly refined estimate with each successive measurement of the individual's location (Figure 3).

Data Structure

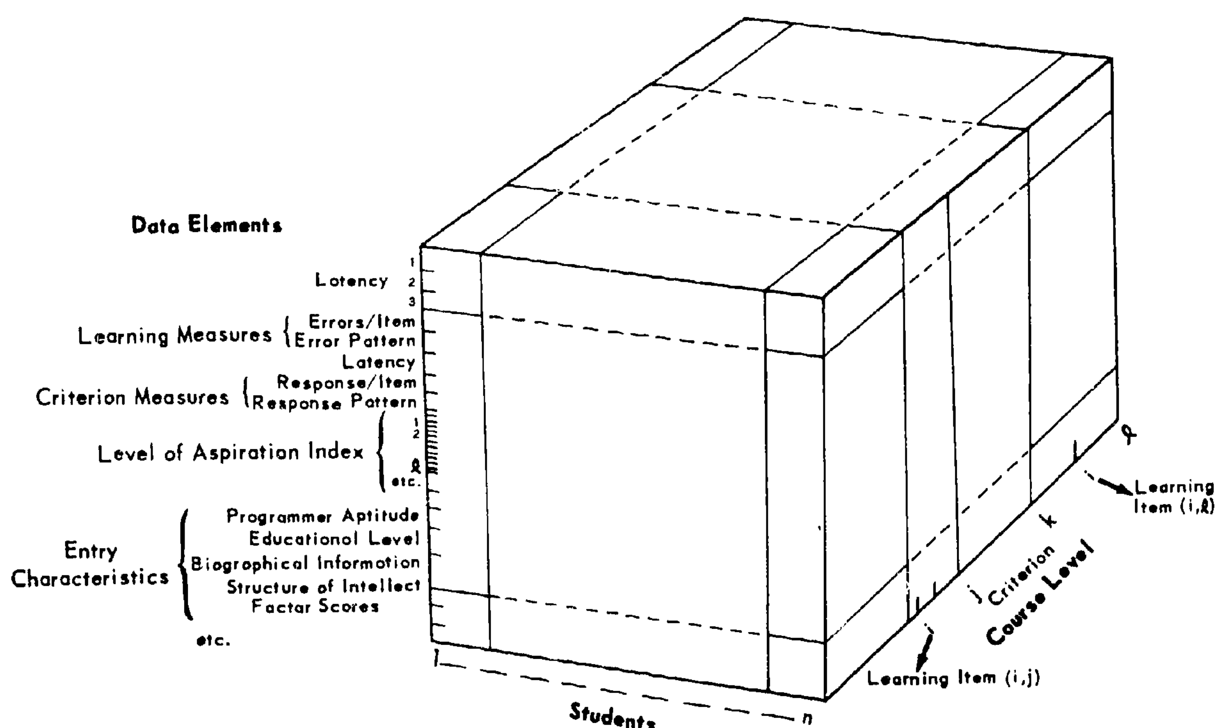

Figure 3

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(3) Implementing these notions takes the form of a type of cybernetic system within which one models the parameters of learning for descriptive purposes and those of instruction for prescriptive purposes. This, in turn, implies manipulating certain characteristics for the decision-making capability within an instructional model and correlating the effects of other variables (intuited to have an effect upon criterion performance but awaiting substantiation for various weightings within the next cycle of the evolving instructional system). The abreviation "SOS" in Figure 4 refers to state of skill diagnoses or state of understanding diagnoses interpreted by the model which in turn selects instructional options (acceleration, remediation, or specialized forms of inquiry) relevant to a particular student. The characteristics referred to in both Figures 3 and 4 exemplify the current approach used by the CAI project at HumRRO (Seidel, *et al.*, 1969, a) but the cybernetic metasystem approach for developing more effective and efficient control processes of instructional systems is generalizable to other efforts.

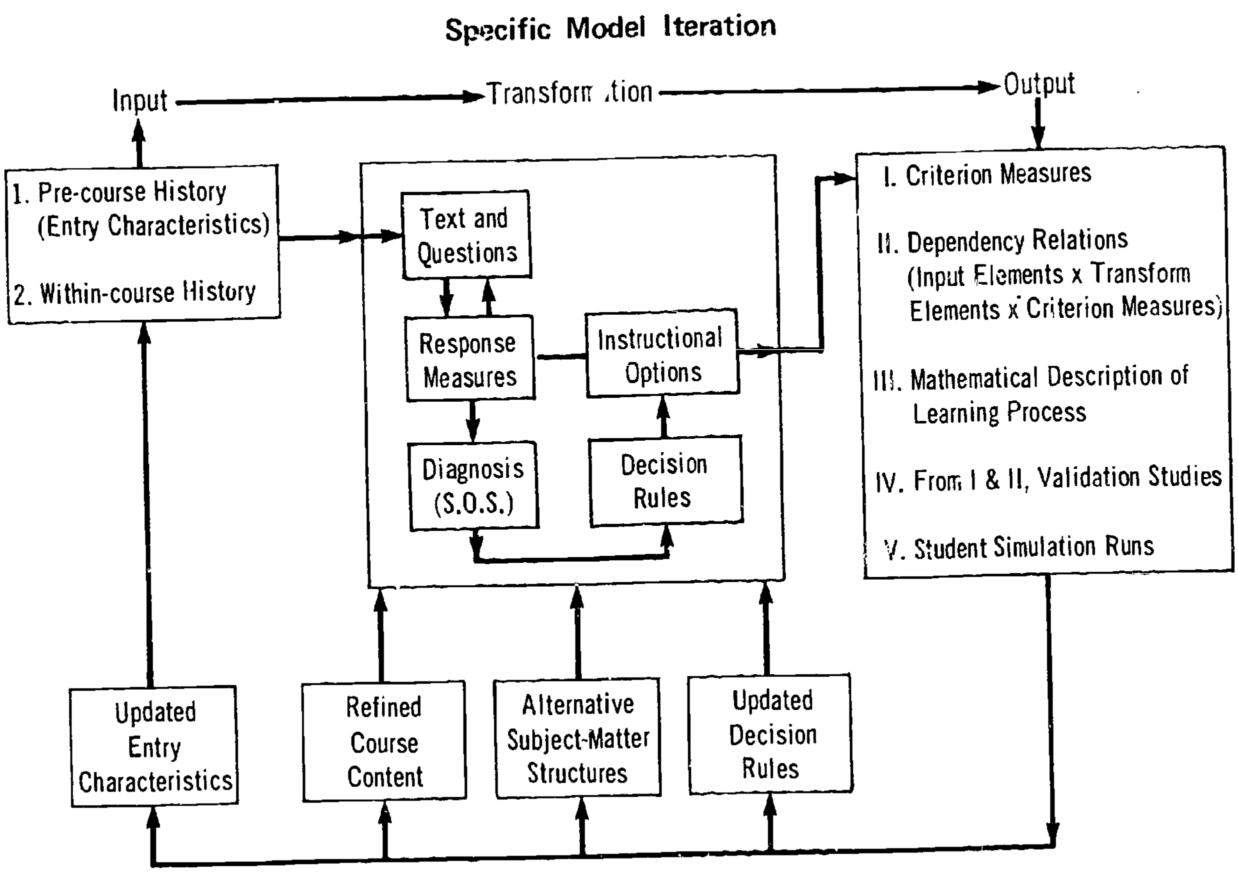

Figure 4

13

Appropriate use also requires, as indicated in Figure 4, implementing as well a description of the subject matter (e.g., Gagne's (1969) notion of task taxonomy) so that an order or structure can be placed on the subject-matter. And, secondly, some notions of intellectual and personal functioning (e.g., currently in our system as given by Guilford) must be incorporated within the context of individual characteristics. What individual differences will prove to be important can be intuited beforehand. However, weightings and specification of these characteristics as a closed space awaits empirical verification.

From a learning-theoretic approach, it is clear that one bias that obtains by definition in the construction of individualized curricula or programs of instruction is that in fact individual differences do make a difference in the effectiveness and the efficiency of instruction. There is an *experimental* fact of life. A continuing problem of measurement and adaptiveness in this regard is within the framework of the iterative approach. Of practical necessity, we will be dealing with grouped (similar-appearing individuals) measures while applying the findings to individual students. We can only strive to make the effect of error diminish through continual refinement of diagnostic measurement.

(4) With respect to the role of the computer in studying and making effective individualized instructional strategies, some researchers advocate the use of CMI, or computer-managed instruction, as the most feasible route to follow in today's educational environment. Others would advocate the use of the computer as a problem-solving aid in this same so-called conventional environment. I have previously made the point (Seidel and Kopstein, 1968) that the futility of assessing the value of computer-aided instruction in this manner resides in the fact that in many such applications the remaining elements of the instructional processes, the implicit strategies, are never available to detailed measurement and systematic variation. This is a limitation of the CMI usage, not a negation of either CMI or computer-aided problem solving, or drill-and-practice in using the computer, or computerized testing.

(5) The intent here is to state that whenever the computer is to be used in these subsets of instructional decision making, it is essential that the remaining elements of the instructional-decision process, the instructional strategy, also be *explicitly* available for study. Therefore, it is perfectly appropriate to use the computer in conjunction with such other "objectifying" types of instruction as programed instruction (whether it be through the use of the films, tapes, or texts). Using such techniques, the instructional decision making, the objectives, the achievement units desired, and so on, are all made quite explicit; the effects of strategy elements can be measured, and systematic variation can be made possible in the interests of effective and efficient progress in studying the roles of various characteristics in instruction that stem from the student or the input characteristics. These techniques, however, should be used in an integrated approach with other types of use of the computer, for example as a tutorial technique in which the total instructional decision making is included in the control process (student and system shared) and adaptive in the largest sense. (Diagnostic measurement of error output is provided from both the student and the instructional material.)

Perhaps what I have been advocating is not new to many of you. However, it is notable that psychological research in the area of learning for 50 to 60 years operated on the implicit premise that the nature of the input event must be held constant and to a minimum of structure; secondly, that the output requirements of the organism must be highly delimited to very simple, physically identifiable responses. The confluence then of the persistence of cybernetic-based theories with the advent of the computer and the rise of considerations of artificial intelligence, as well as the interest in individualized instruction, will lead the way toward a new era of mating human learning theory development with instructional strategy and optimization within the educational environment.

[1] Reference is made to the fact noted at the outset that learning research is pertinent to a subset of management requirements, albeit an important subset. One must also consider problems relevant to identification of relevant student attributes and respective values, as well as appropriate partitioning of the subject-matter. In signal detection terms, the job of the instructional strategist consists first and foremost in being able to score hits as a relationship established between his observing characteristics and the relevant characteristics of the student. Thus, we are dealing with a type of conditional probability related to hits, false affirmations, and the other parts of the two-fold contingency table. (Incorrect identification of what is perceived to be a relevant attribute, correct identification of an in fact irrelevant attribute, etc.) In terms which would relate this to the partitioning of the subject-matter in a particular partition with the attribute values of the student.

Thus, we are dealing with conditional probabilities relating to the possession by the instructional agent of the proper observing attribute and the probability of identifying that attribute value within the student (call it p, conditional probability of a hit). Secondly, the conditional probability, r, of being able to match the attribute values possessed by the student with the proper attribute values identified within the subject-matter partition. Now, enter the application of learning theory. Thirdly, the probability t is the likelihood that the instructional agent will take appropriate action to increment the learning state of the student once the instructional agent has identified and matched according to probabilities p and r. Statistical decision models (Swets, 1963) seem to hold a good deal of promise for the identification problem but the problem of adjusting the instruction (the strategy or algorithm) remains; that is, given that the "hit" occurs between the instructional agent observing the S possessing pertinent attributes, the instructional agent must still take appropriate action to increment the learning state. Of course, the parameters p, r, and t will still require the subscript and superscript to reference the individual.

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